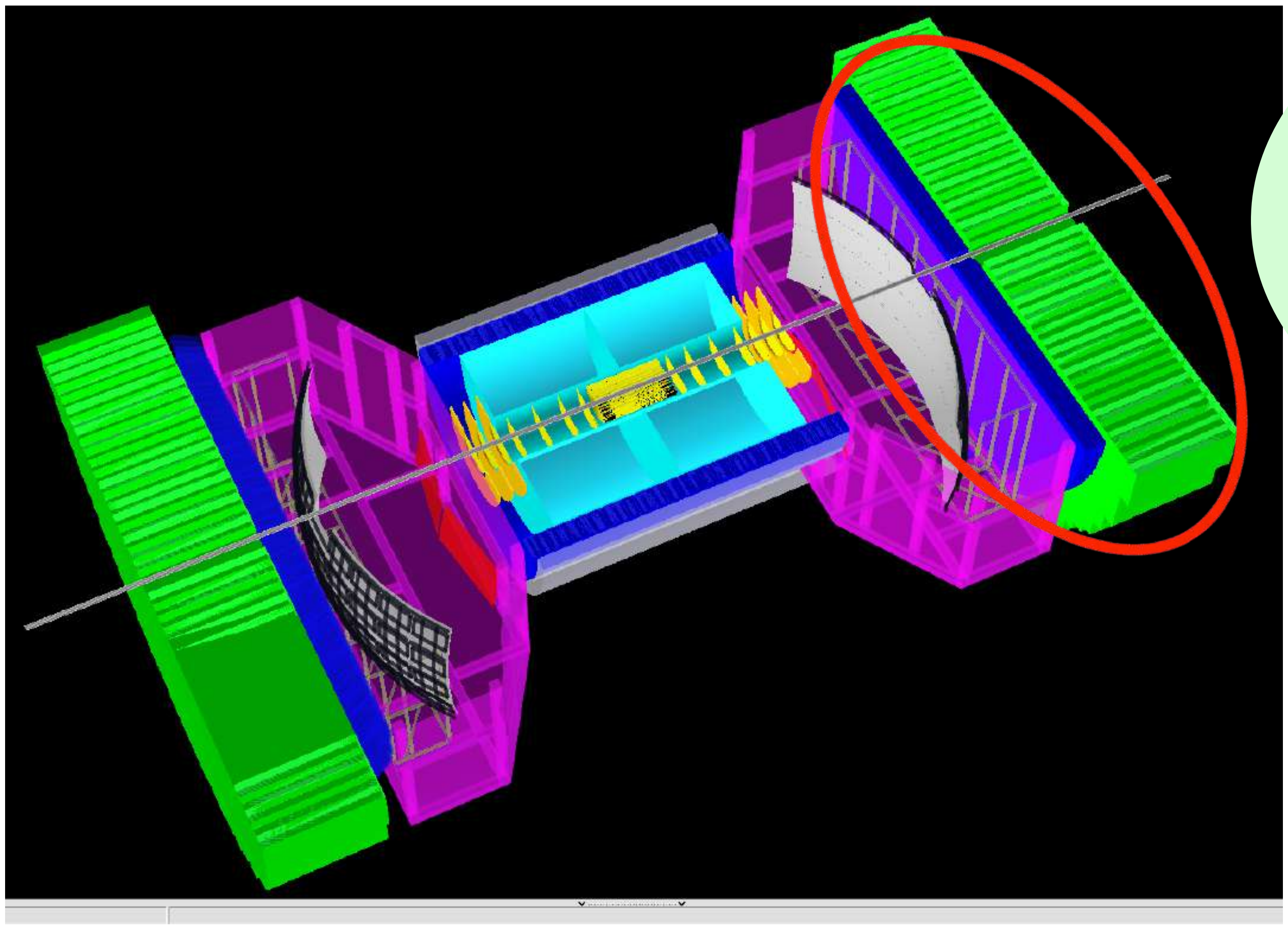
eRD1, Forward Calorimeters Developments.

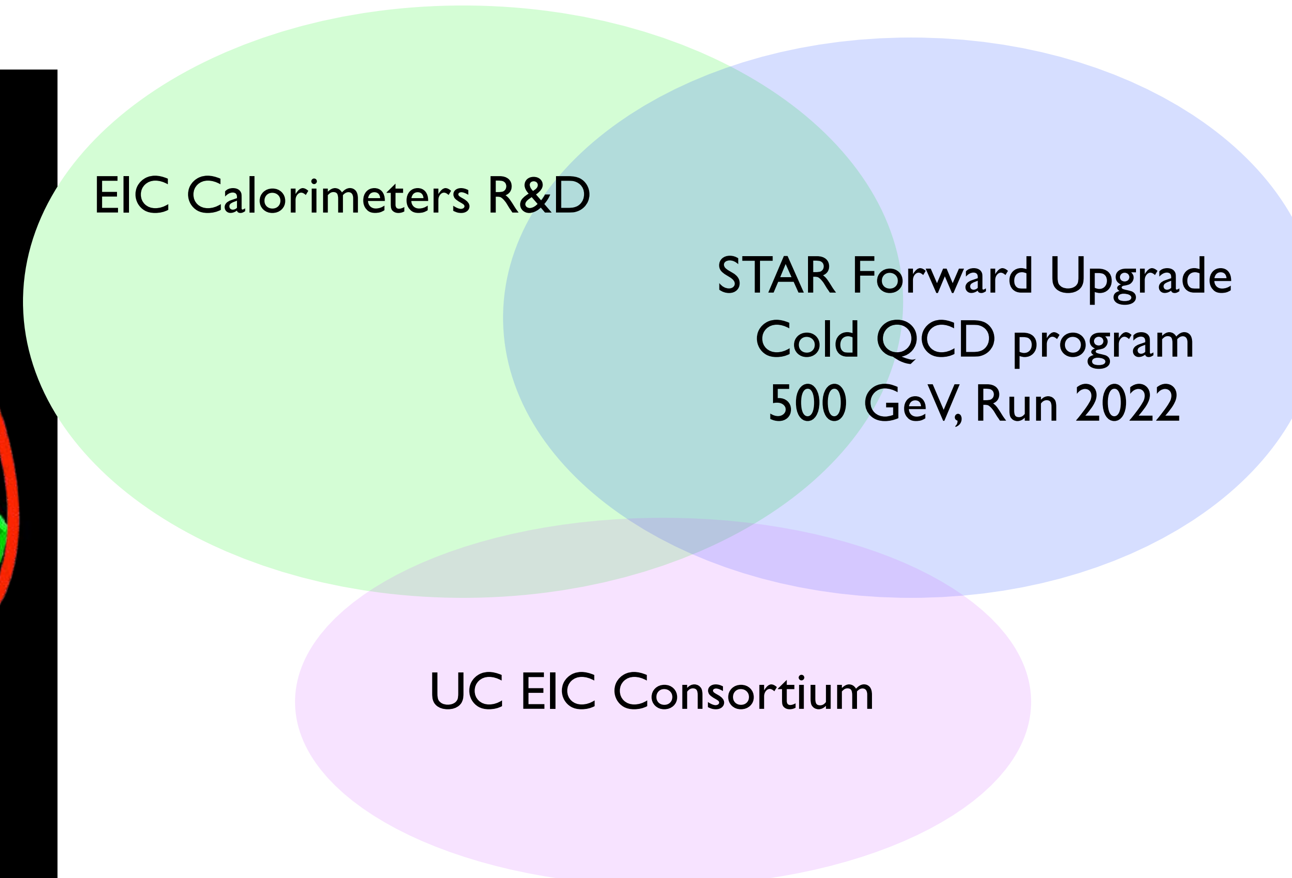
(UCLA, UCR, TAMU, BNL, IUCF)

O. Tsai (UCLA)

EIC R&D Meeting, BNL July 11, 2019

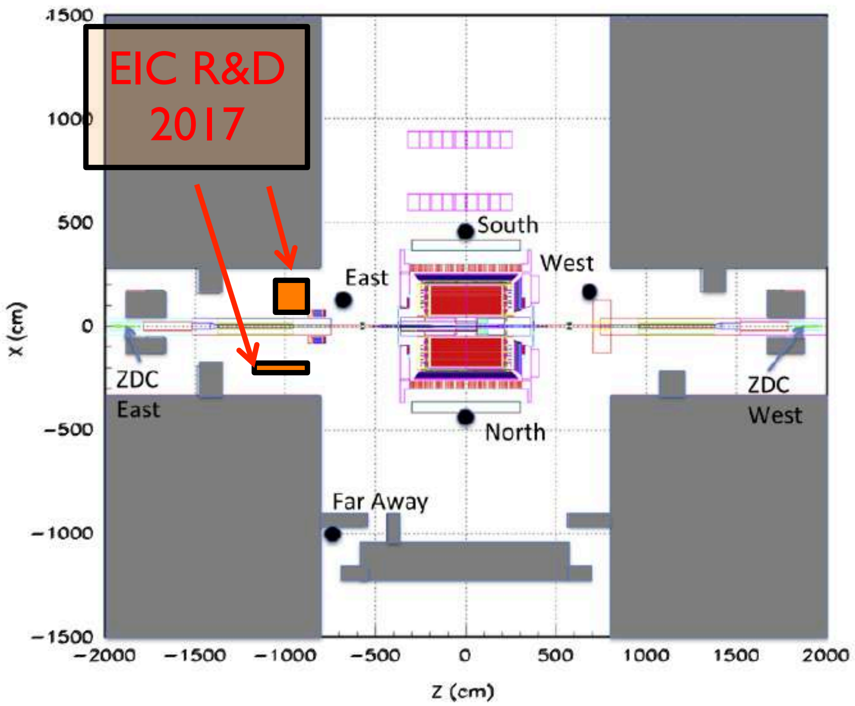
For next few years we want to concentrate efforts on forward Hadron Calorimeters. Central Detector and ZDC.





- People
- Similar desired system performance
- Observables
- Technical Challenges

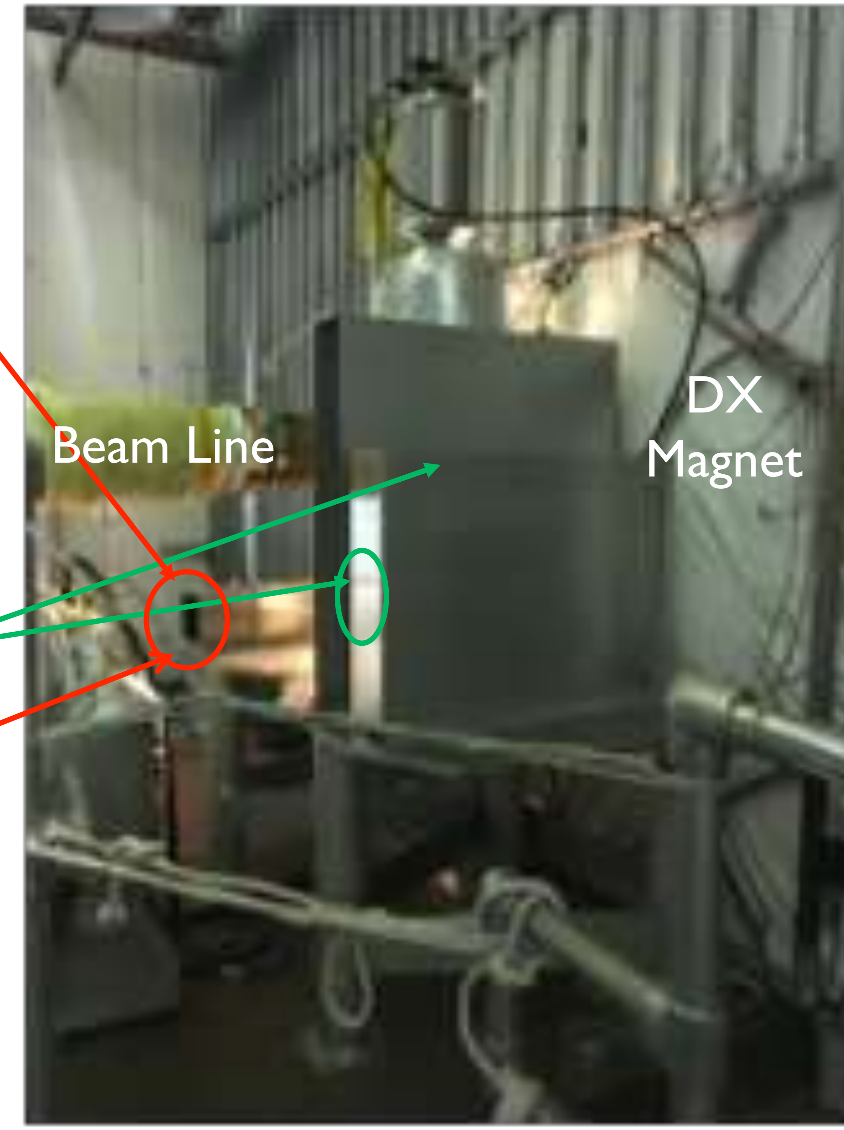
500 GeV pp @ RHIC, similar conditions at EIC



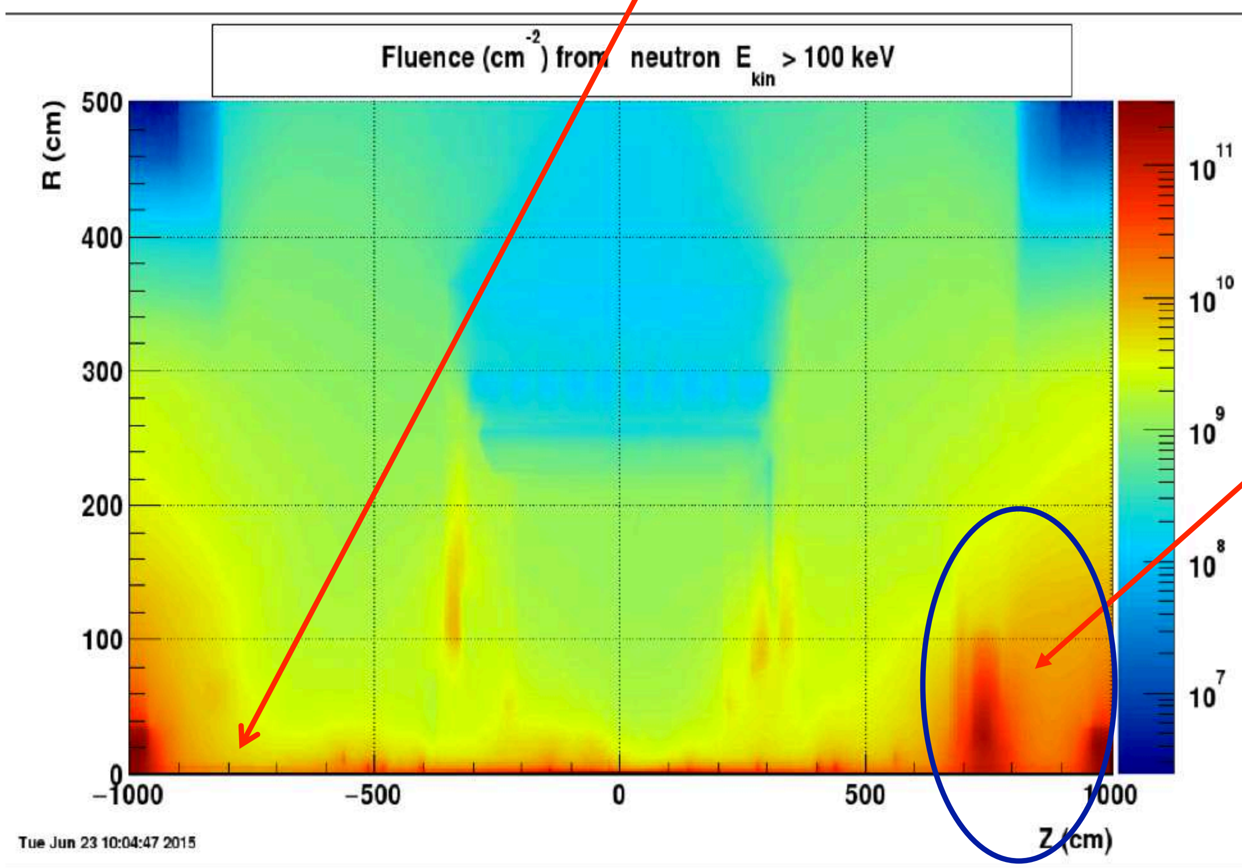
Y.Fisyak, et.al NIM A756

EIC, Run 17 STAR IP:

- 152 SiPM at ~135 cm (since Feb.) . All in Volume 10 x 10 x 2.5cm^3
- 26 SiPMs at ~45 cm (since April)
- APDs at ~45 cm, (since April)

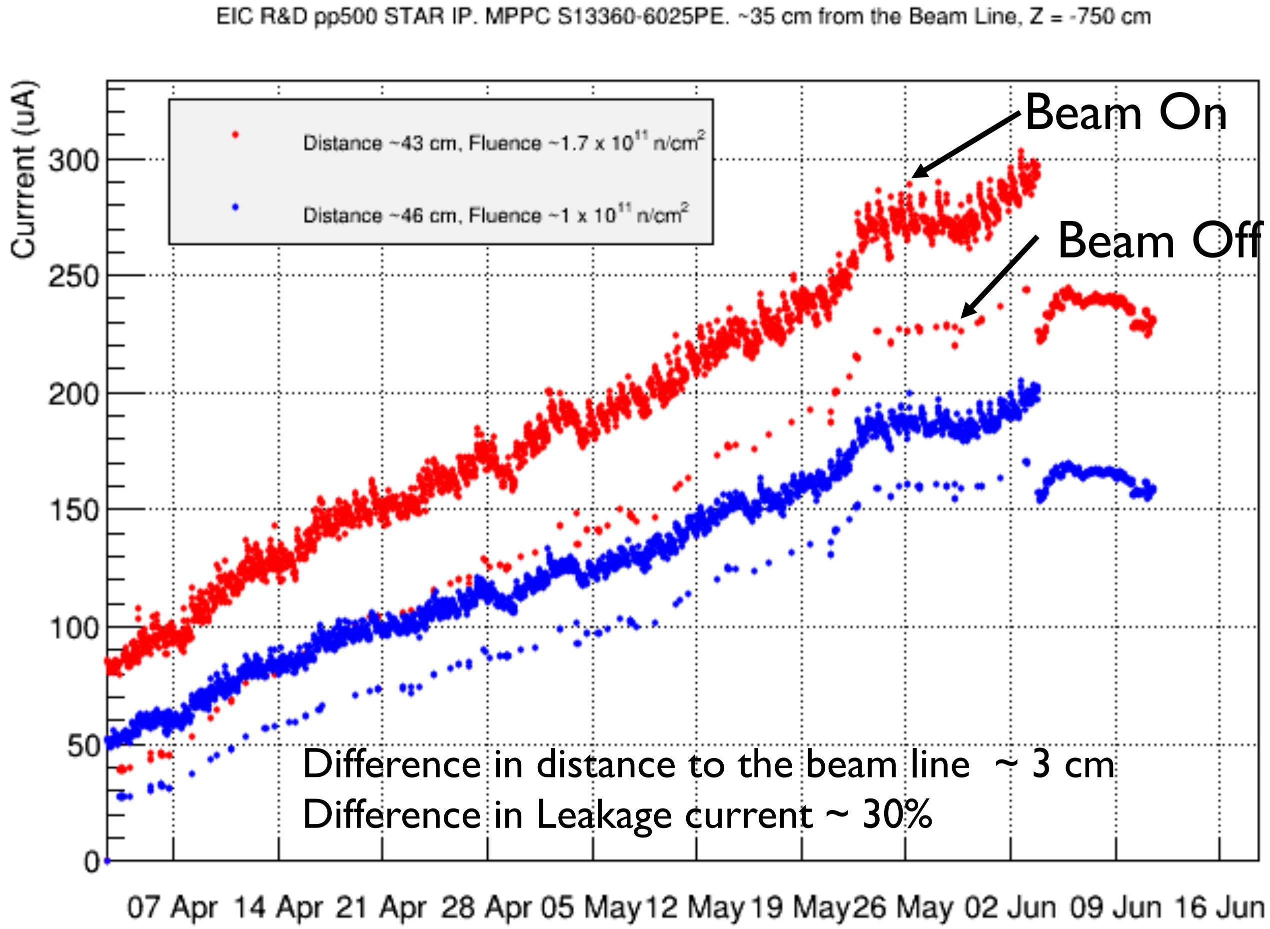


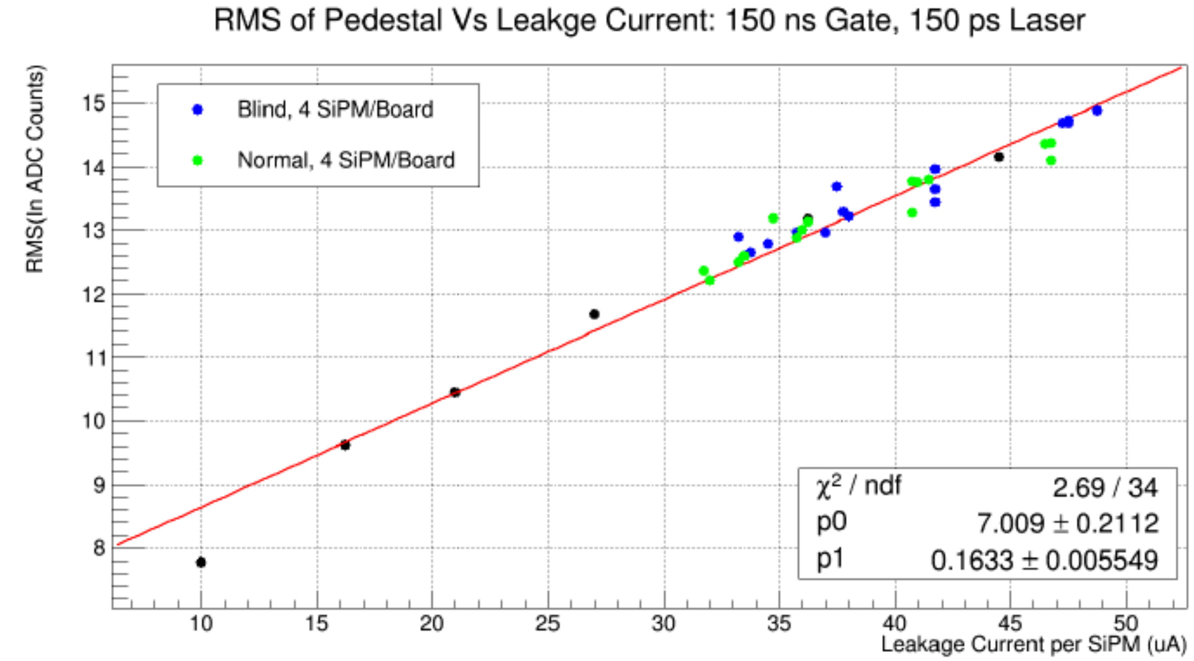
FEMC Run16, Run17

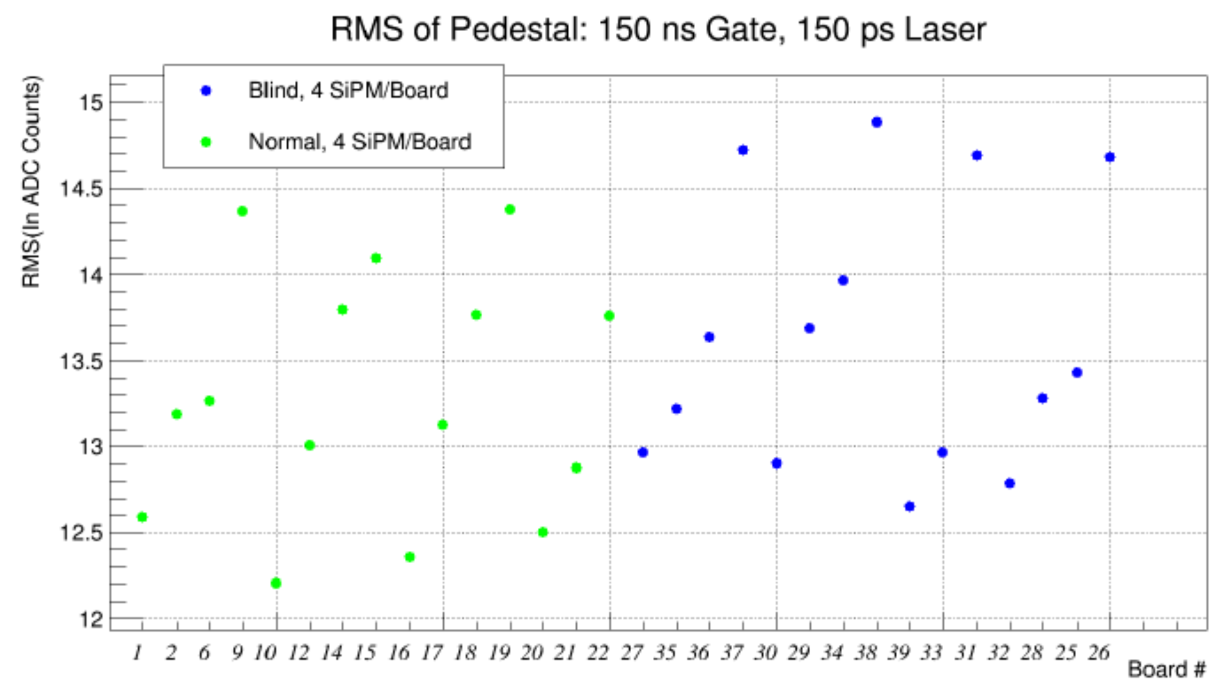


- FCS 2022
- Calorimeters itself are sources of neutrons.
- Size of the system is important.

Run 17. Examples of Degradation.





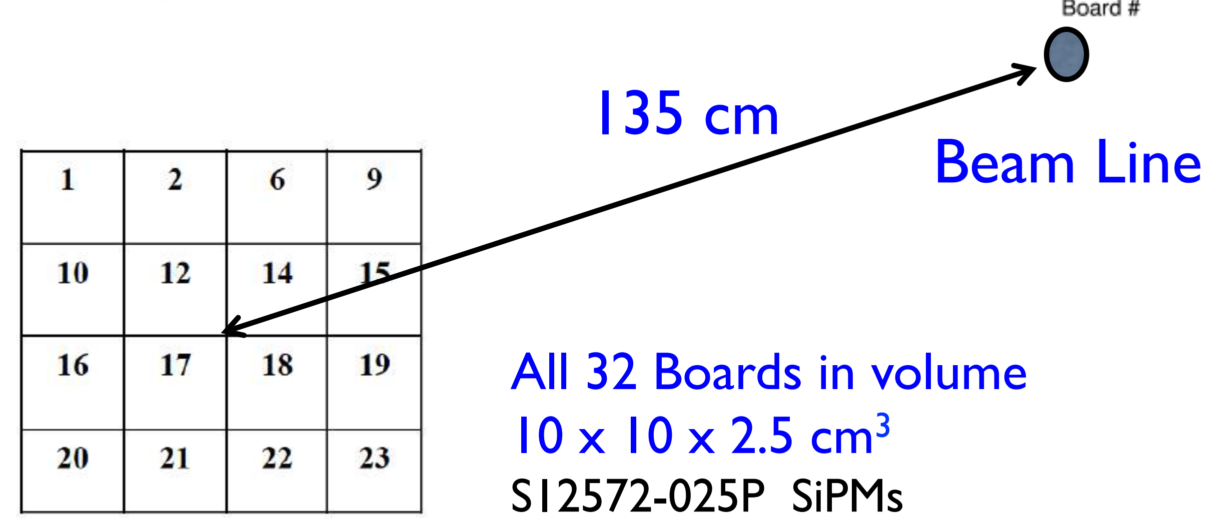


Need collider at right energy and central detector.

After Run17 and followed up lab tests:

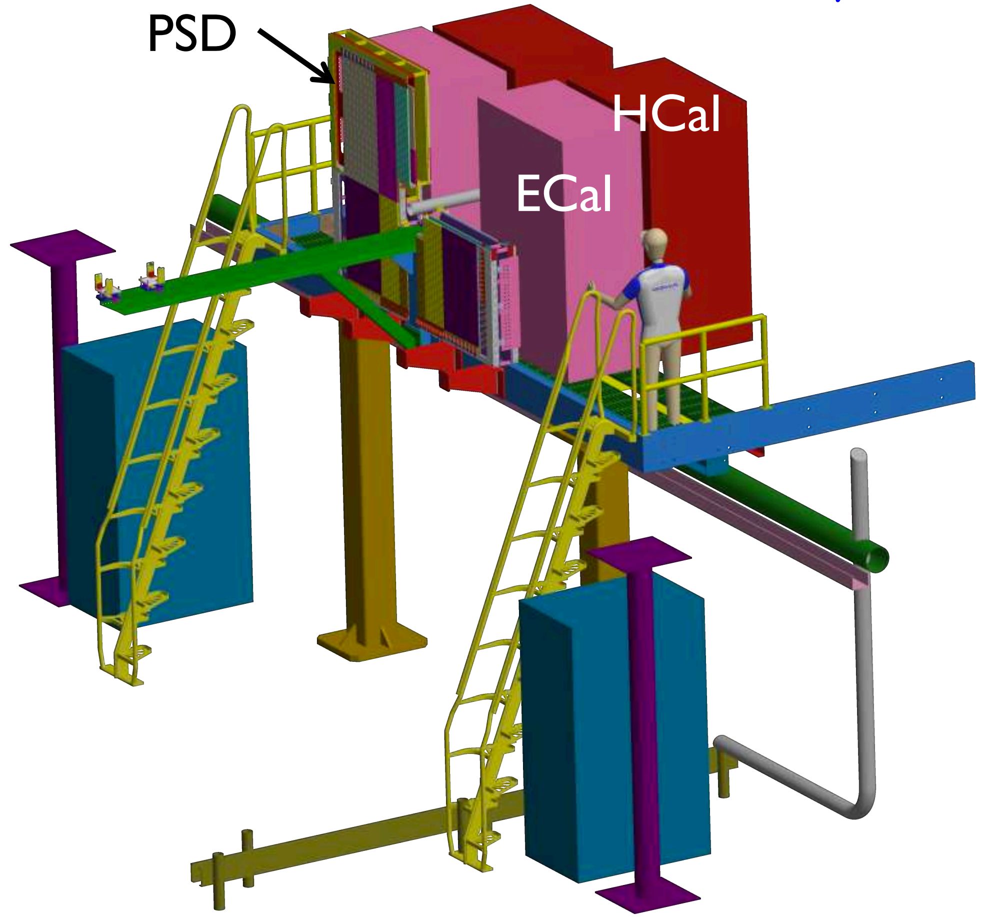
- Very good understanding of mechanisms of degradation of SiPMs at such conditions.
- Practical recommendations for operation and detector requirements.

As was reported in Jan. 2019 meeting.



All 32 Boards in volume
10 x 10 x 2.5 cm^3
S12572-025P SiPMs

Synergies between EIC R&D and STAR forward will continue with realization of Forward Calorimeter System (FCS)



- Preshower – 240 channels
- Emcal – 18 X0, ~0.5 λ, 1496 channels
- Hcal – ~4.4 λ, 520 channels
- Coverage 2.5 < η < 4
- ~ 10K SiPMs Readout for all detectors.

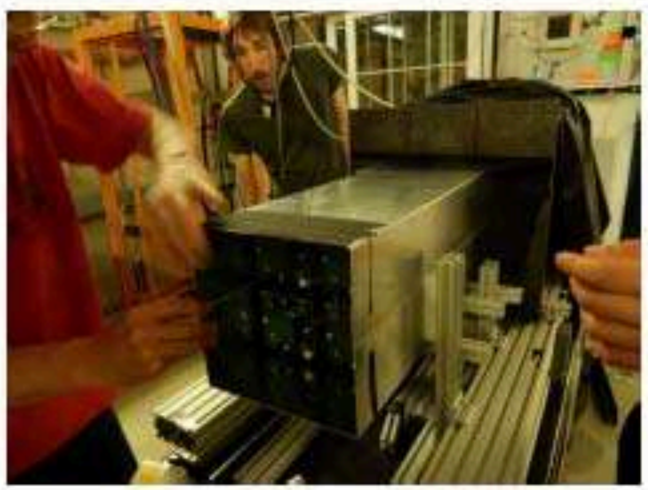
- Successful Director's review Nov. 2018
- NSF MRI Jan 2019
- Very positive response from NSF. Expecting funding at ~90% (~$2M)
- 1500 Shashlyk (PHENIX) towers modified for SiPM readout and ready for installation.
- Full scale prototypes (Ecal + Hcal) tested at FNAL, taking data at STAR since May 22'nd.

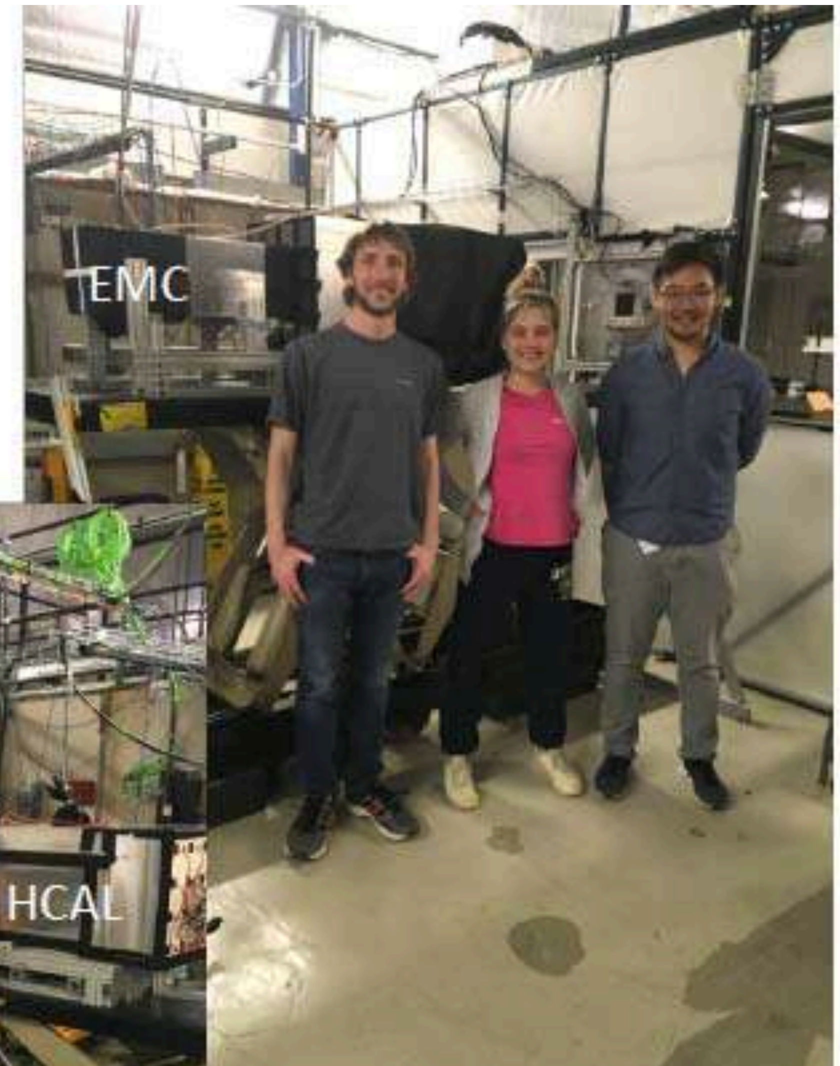
1. Abilene Christian University
2. BNL
3. UCLA
4. UCR
5. Indiana University, CEEM
6. University of Kentucky
7. Ohio State University
8. Rutgers University
9. Temple University
10. Texas A&M University
11. Valparaiso University
12. Wayne State University

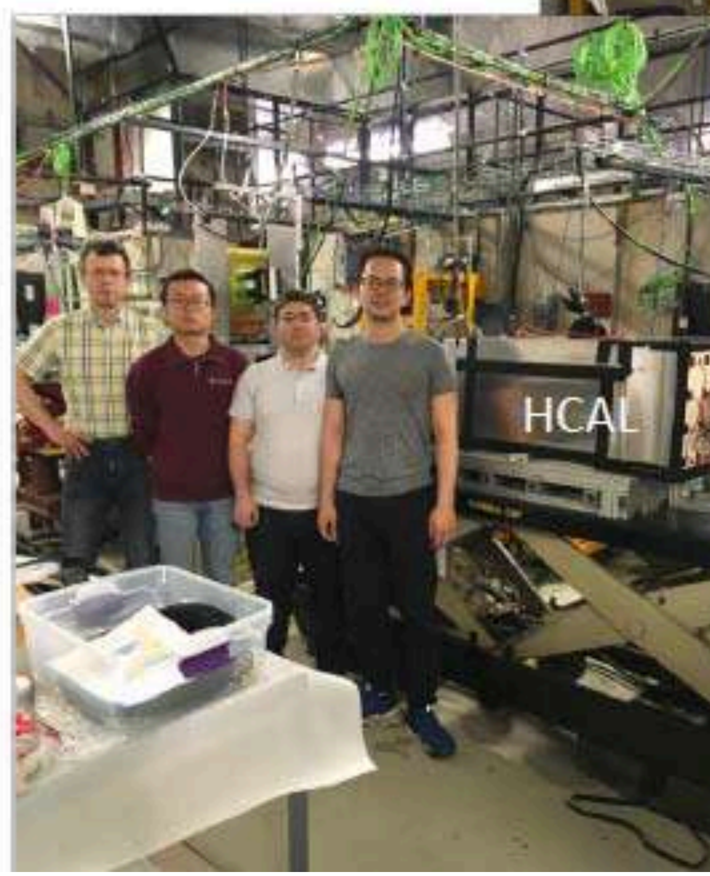
Cold QCD program and FCS made possible first Test Run for UC EIC Consortium.

- Re-used cold QCD Forward Calorimeter parts (Fe/Sc, 20mm/3mm),
- Changed readout from SiPM to PMTs added (thanks to Y. Goto for help).
- 1 GHz WFD DAQ (thanks to M. Putchke for help).

FCS, April 2019
FNAL Test Beam
4x4 Ecal, 4x4 HCal







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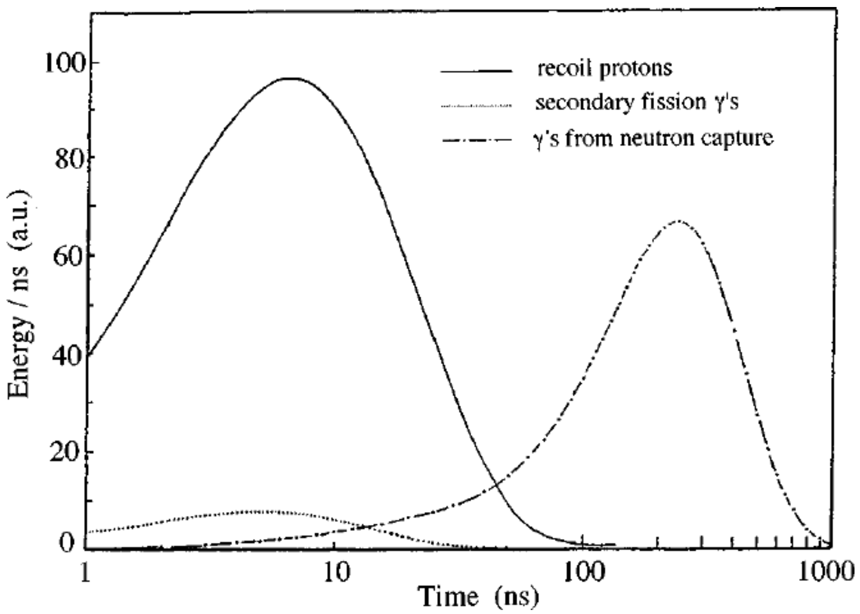
For EIC R&D goal was to measure timing properties of signals from Hcal.

Time scales for HCAL signals.



ZEUS, NIM A263, 136 (1988)

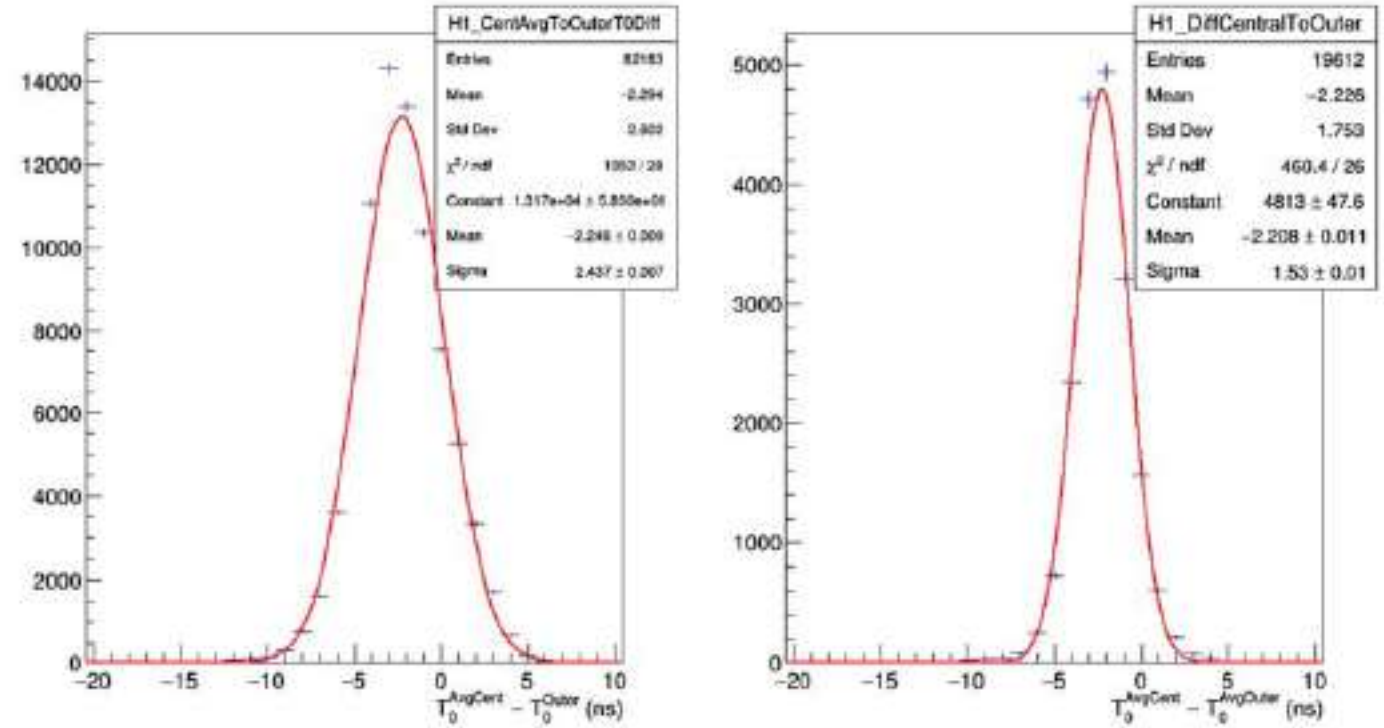


Figure 2. Difference in T0 in central and peripheral towers of HCAL.

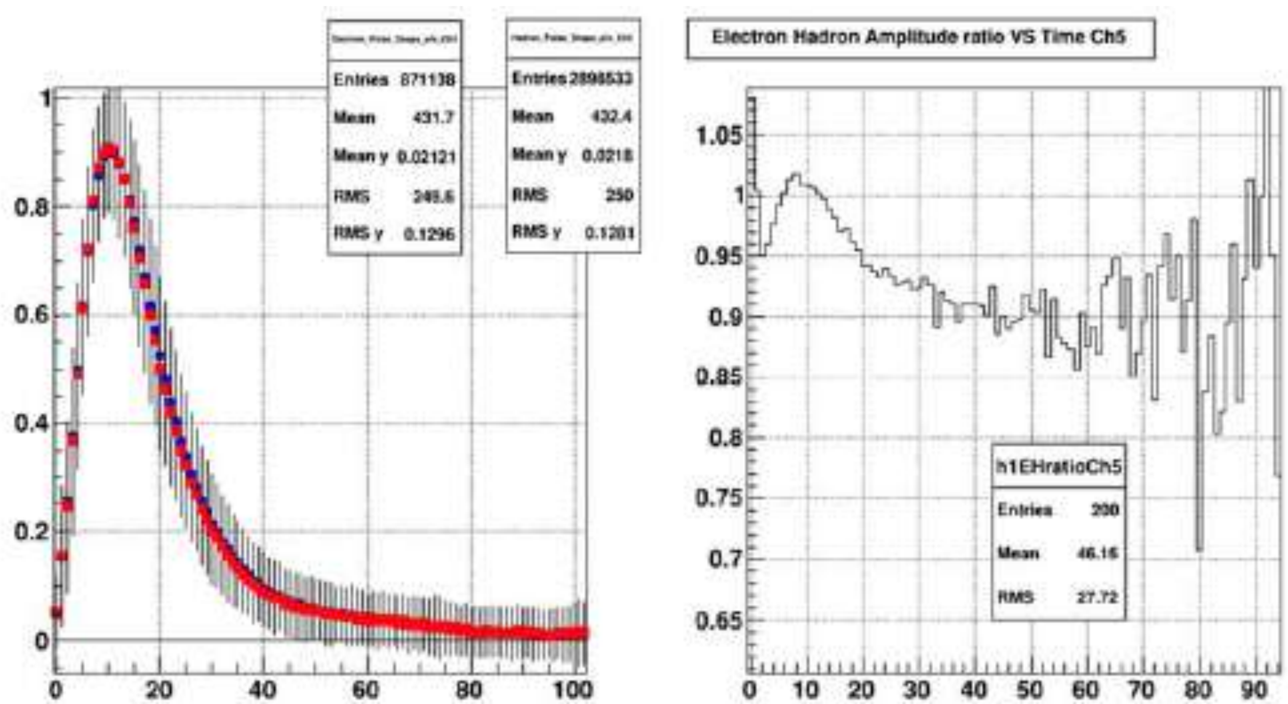


Figure 3. Shape of signals for 20 GeV electrons and pions. X axis bin size 1 ns.

- 'Sanity check', T_0 difference between central and peripheral towers in Hcal.
- Direct comparison of signal shapes from electromagnetic showers and hadronic showers shows hints of contribution from recoil protons.
- Signal is too week to make e-by-e corrections, i.e. no correlations observed for short/long integration time and total energy.

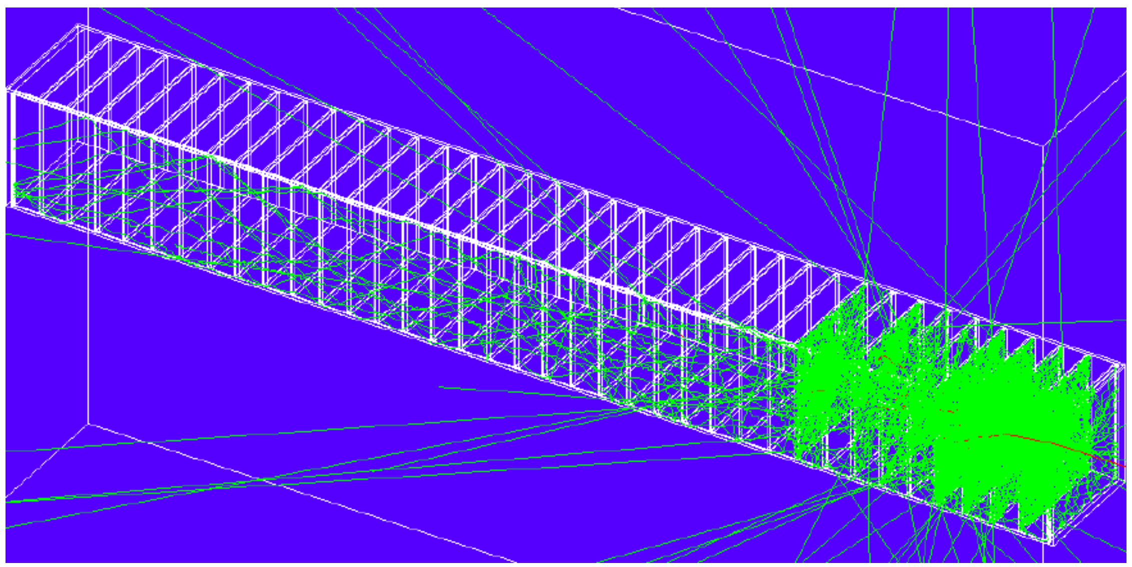
N.B. FCS (Fe/Sc) structure was not optimized in any sense for such purposes.

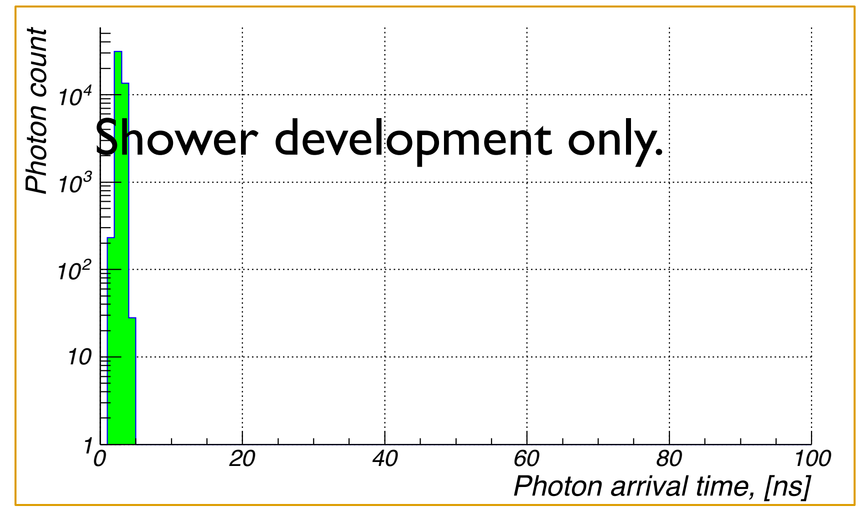
MC: GEANT4 model.

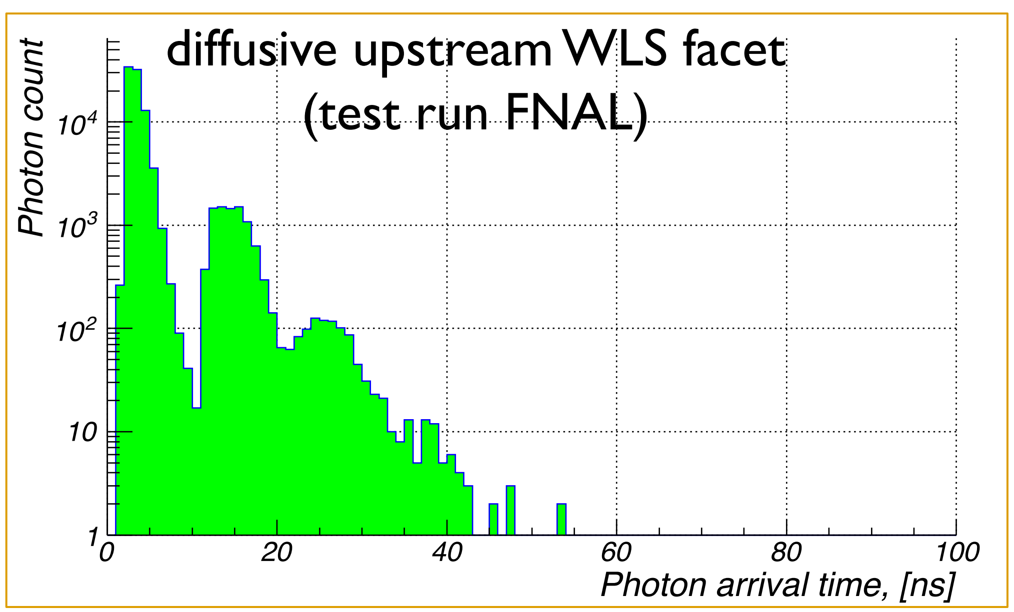
Microscopic description of the shower development:

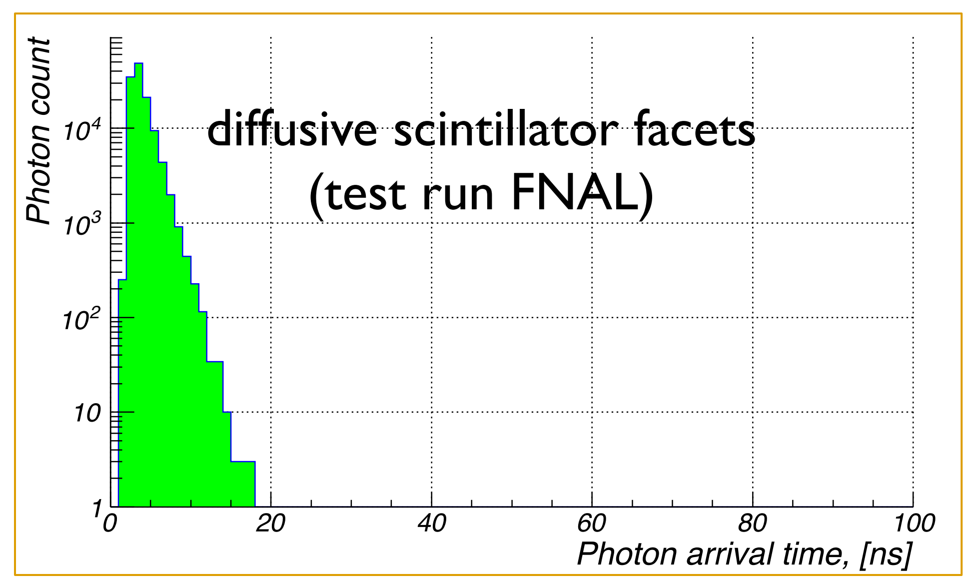
- Shapes, materials, optical properties of volumes and surfaces
- Custom physics list: a mix of FTFP_BERT_HP and optical photon stuff; Birk's correction
- Shower development, scintillation, absorption and re-emission in WLS material

-> observed signal is defined as a number of optical photons crossing the downstream WLS facet in 1ns time bins (similar to test run at FNAL).





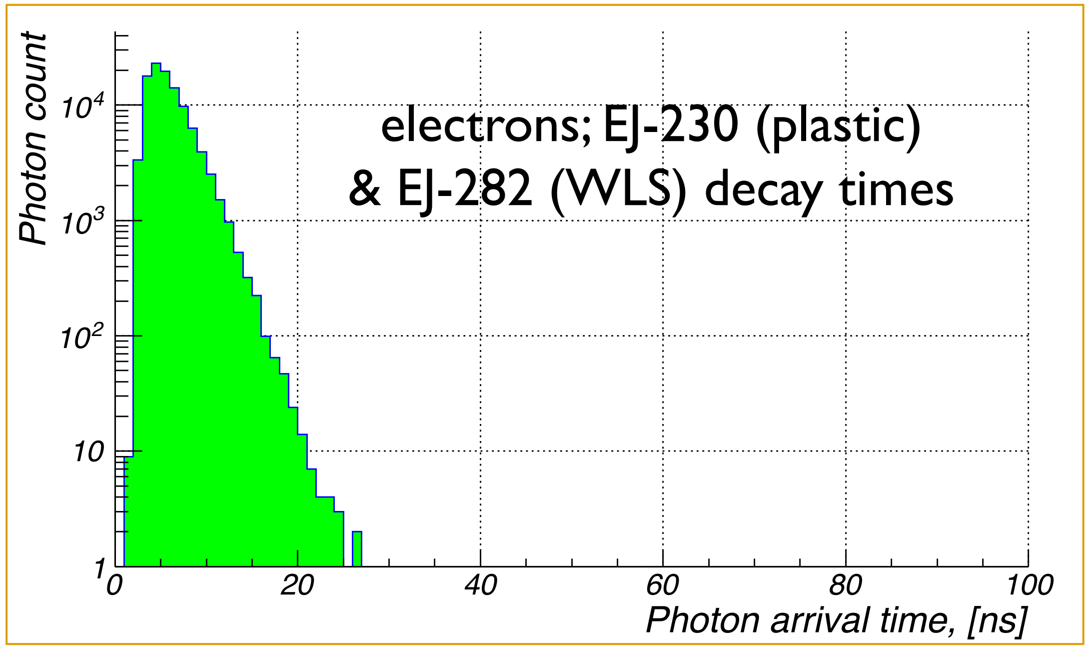


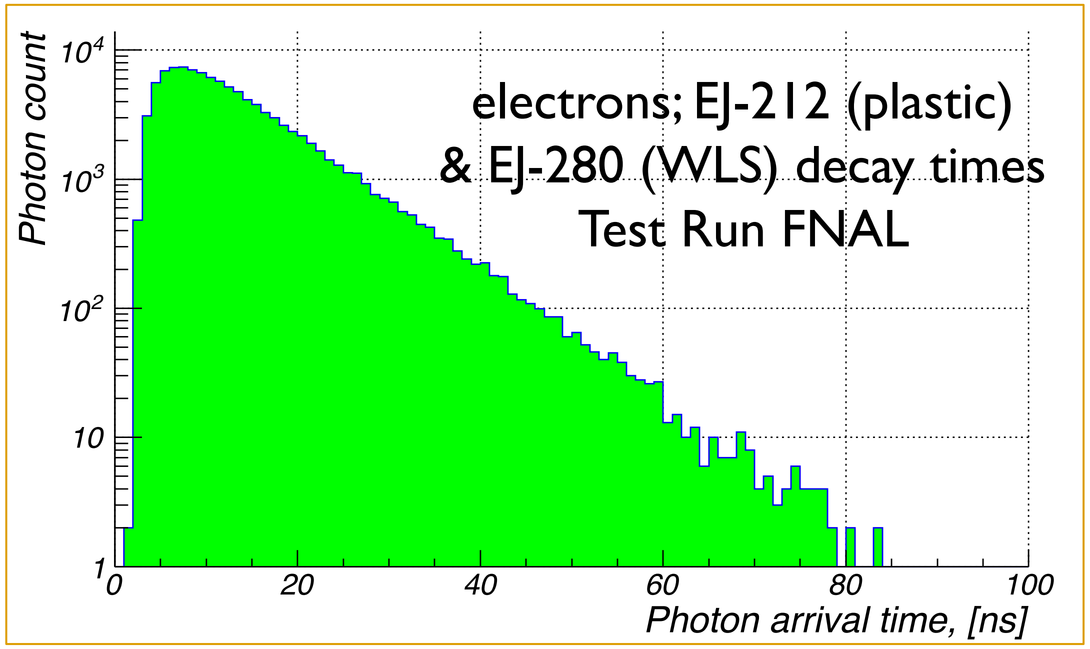


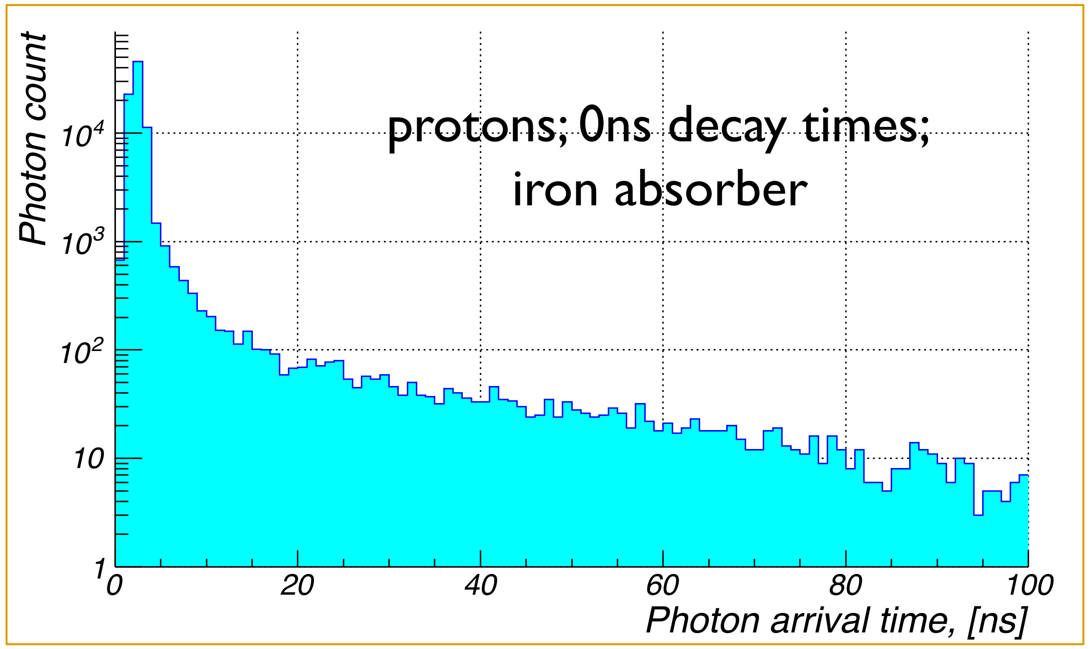
-> all relatively small effects, although making upstream WLS facet diffusive should be avoided

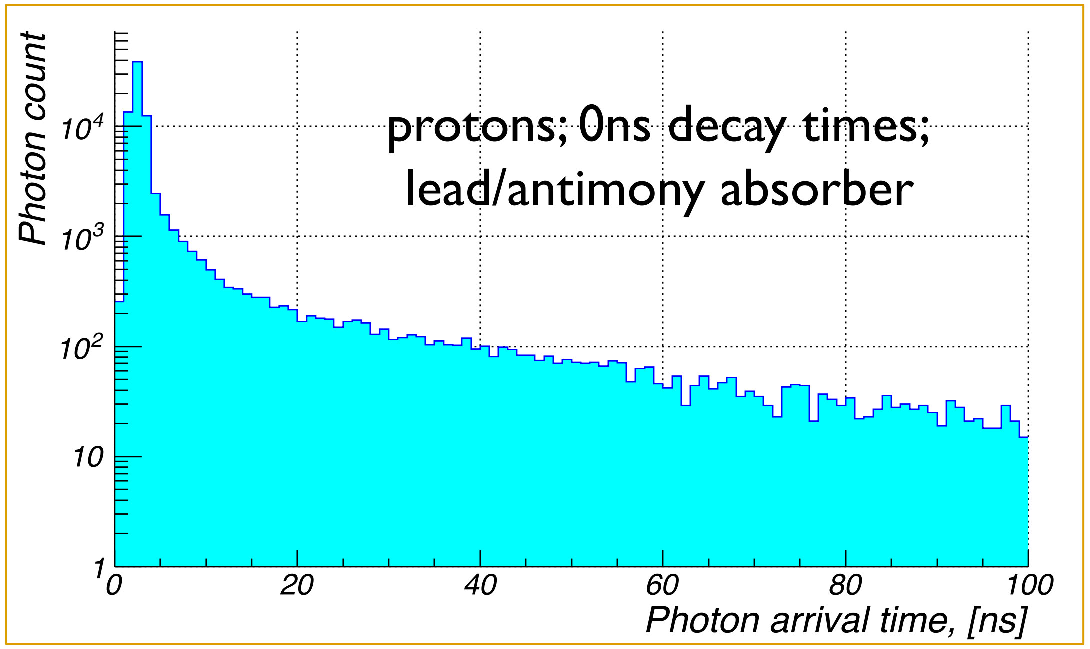
MC: neutron tails vs plastic decay times

- 10 GeV electrons and protons
- Diffusive reflection (causing photon bouncing) turned off in all places







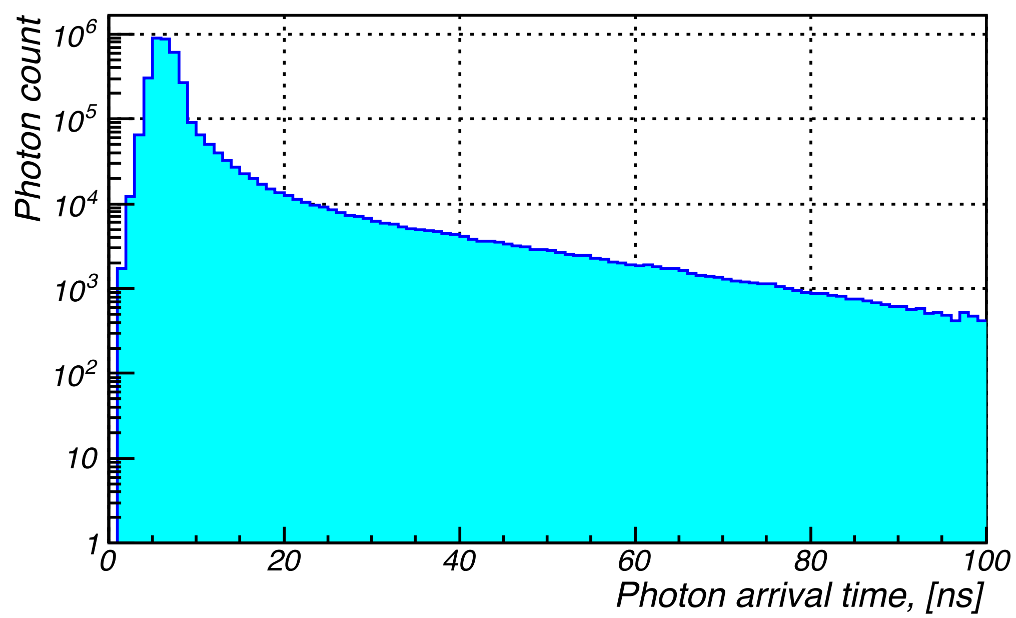


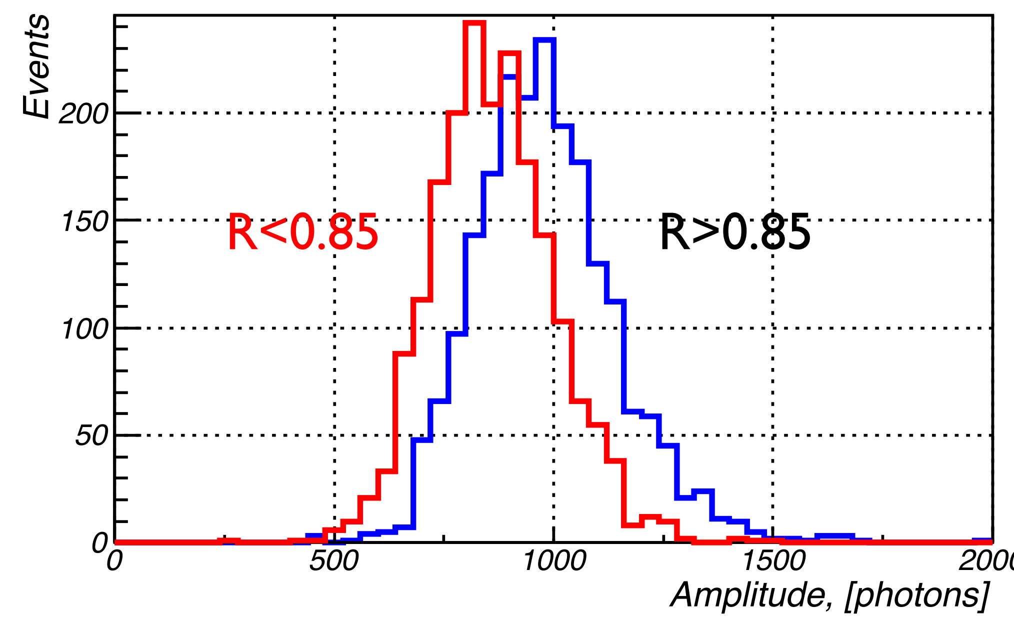
-> clearly lead absorber produces more neutrons …

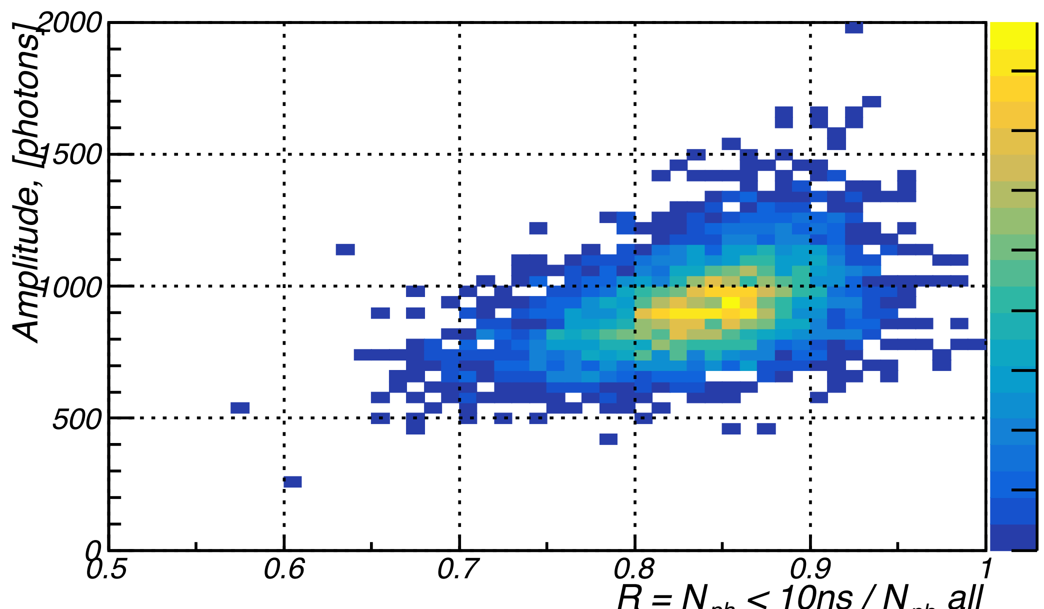
… but it does not really help with slow plastic

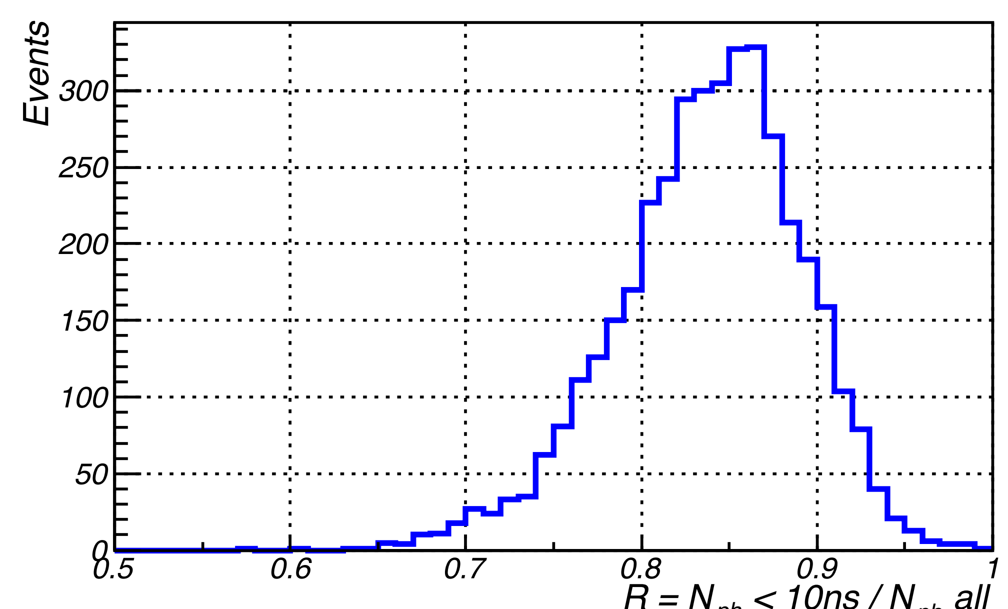
MC: dual gate energy correction study

- 10 GeV protons
- 90x90x240cm^2 calorimeter size; 17mm (lead) + 6mm (plastic) cells
- “ideal” light collection scheme; 0ns plastic decay times



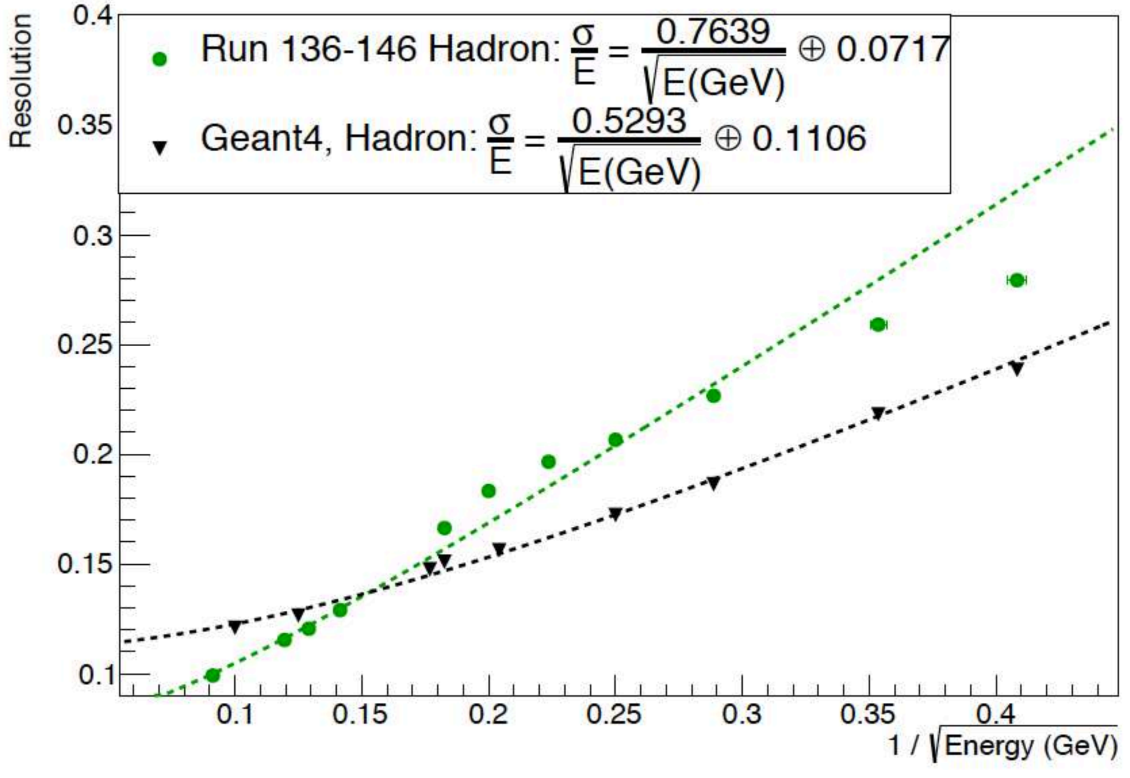


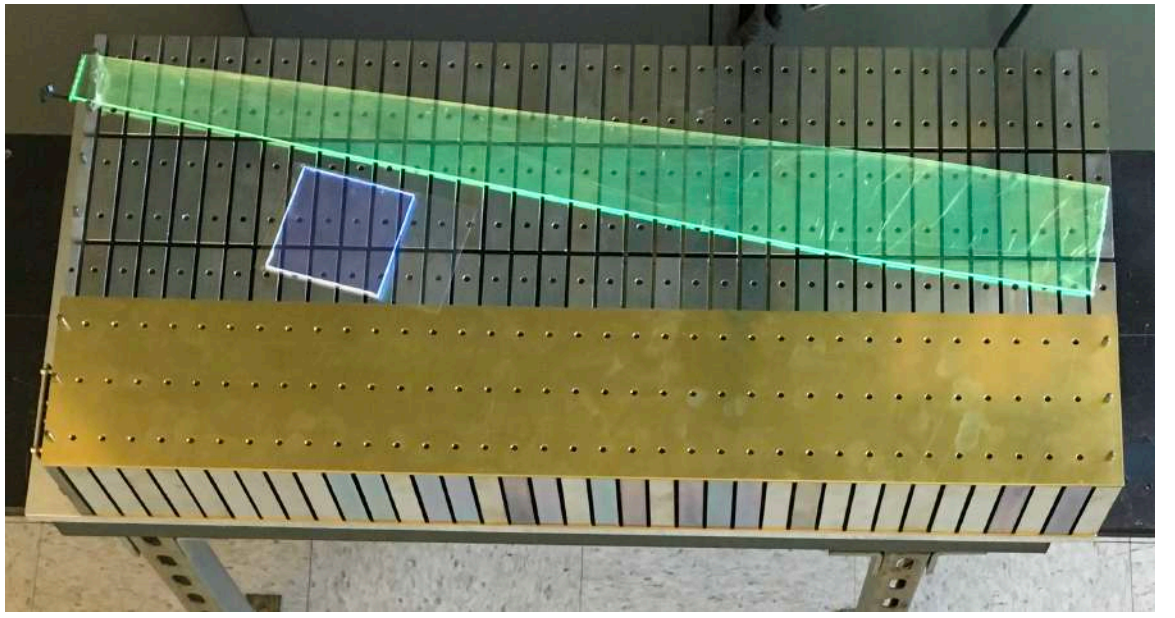


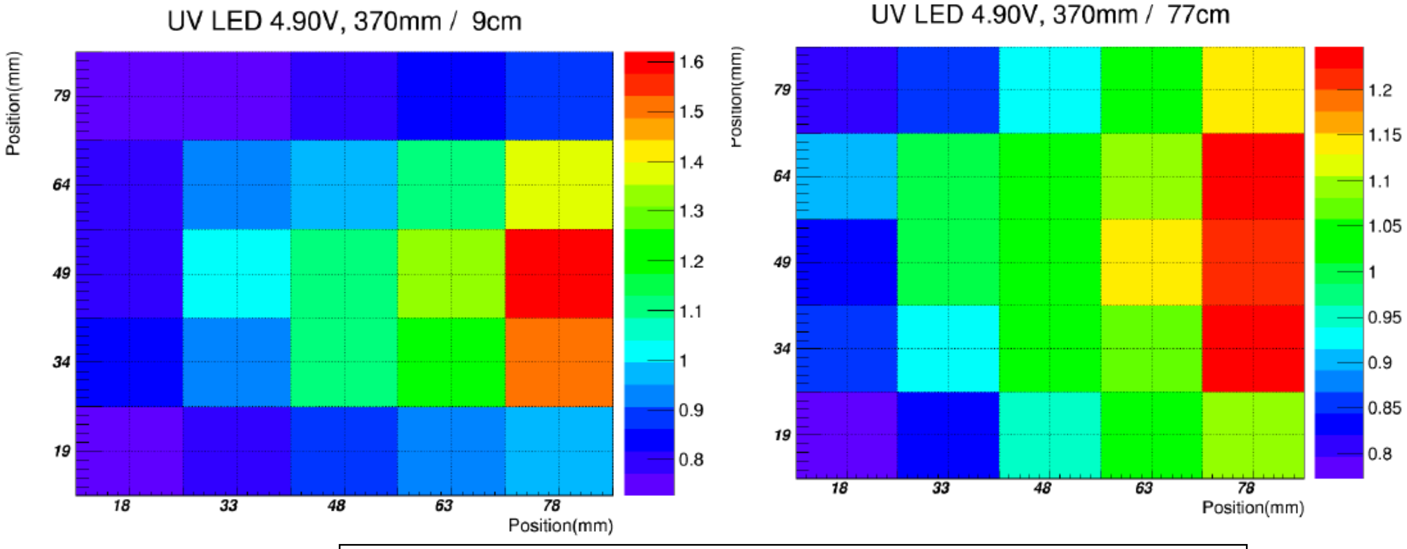


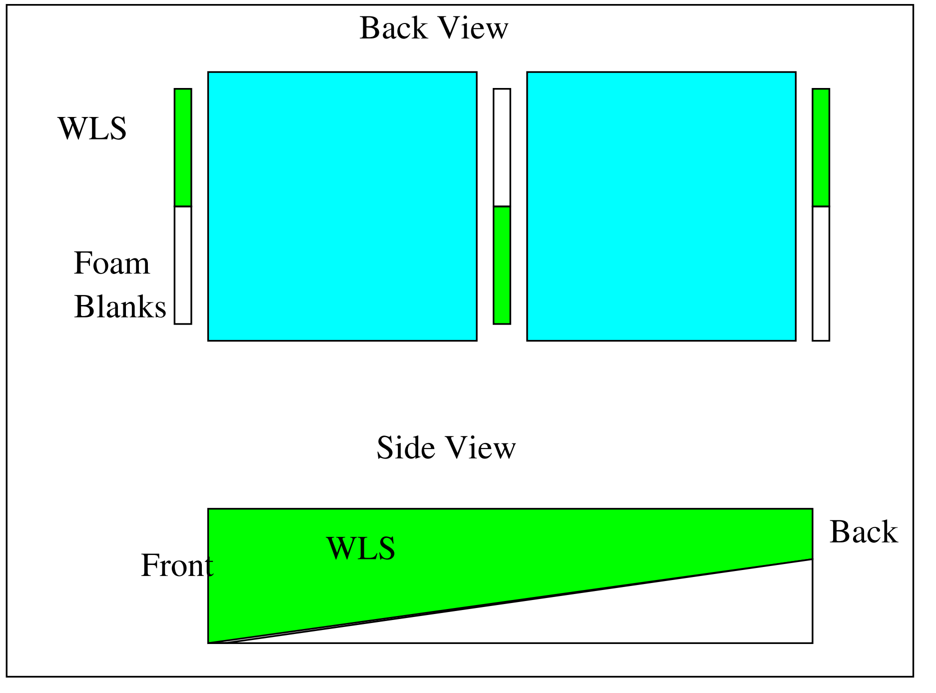
-> first quick study shows some effect …

… but it is rather marginal for this particular configuration









- Need for slow MC for central detector as well.
- There is discrepancy between MC and GEANT4 for (Fe/Sc + Shashlyk) system.
- Suspects, transverse non-uniformities in light collection from Sc. Tiles.
- No discrepancy in 2014 data/MC for W/ Scfi + Pb/Sc. Finer sampling. More shower particles.
- FCS – running validation that 'leaky' light collection scheme for hcal work well.

Summary and Plans:

1. Synergy between STAR Forward and EIC R&D was very productive, now UC EIC Consortia will add to that.

2. MC machinery for detailed timing simulation of shower development is in place.

3. Z. Xu (UCLA) partially supported from UC EIC Consortia will lead efforts with initial help from M.Sergeeva (UCLA) and A. Kiselev. to continue detailed MC studies.

4. Short opportunistic test run at FNAL by UC EIC Consortia + BNL + TAMU reveal that there is no hope to use of timing for dual readout method for Fe/Sc structures. (Central detector). Even with improved timing properties (fast WLS/Sc) signal will be too small for e-by-e corrections.

5. For Pb/Sc it may work. There is opportunity to check it by borrowing about 2k needed scintillation tiles from construction of FCS and using existing Pb absorber plates at FNAL, and reusing same PMT readout and DAQ used in test run 2019. (has to be done in spring 2020). Goal is to get definitive Yes/No for any future timing type developments for ZDC.

6. Need to run bench tests and include realistic detector responses (PMT, fast WLS, Sc, surfaces treatments) in simulations before committing hundreds of hours of CPU on detailed simulations.

7. For central detector concentrate on optimization of composition and methods for improving uniformity of light collection, synergy with FCS.

Budget for Sub-Project One

Budget Scenario	100%	20% cut	40% cut
UCLA support for students (26% overhead included)	$12.6k	$12.6k	$12.6k
Travel (26 % overhead included)	$15.6k	$15.6k	$15.6k
ZDC WLS	$12k	$12k	$0k
ZDC Mechanical Components	$4k	$0k	$0k
ZDC Machine Shop (26% overhead included)	$4k	$0k	$0k
Shipping, supplies	$3k	$0k	$0k
Total	**$51.2k**	**$40.2k**	**$28.2k**

20% cut, use existing mechanical components. Lost opportunity to increase sampling fraction.

40% cut, not test run.